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PROPOSAL TO STUDY 70 GEV/C $K^{\pm}$ P INTERACTIONS IN BEBC ASSOCIATED WITH AN EXTERNAL CHARGED PARTICLE IDENTIFIER

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SUMMARY

We present a proposal for an experiment of 300 000 pictures of K^+p interactions and 300 000 pictures of K^-p interactions, both at 70 GeV/c and taken in BEBC associated with an external particle identifier.

We shall study inclusive, semi-inclusive and some exclusive reactions. The main physics interests are production of all kinds of particles and resonances, correlations and clusters, diffractive processes and search for remaining two body channels due to Reggeon exchange mechanisms.

Contactmen: M. Baubillier (K^-) and J. Laberrigue (K^+).

I- INTRODUCTION

The Big European Bubble Chamber is among the instruments that should give physics results as soon as the SPS will get into operation. In addition, the available RF separated beam and the EPI (External charged particle identifier) will allow a study of $K^{\pm}p$ interactions, maybe, before similar experiments are done at FNAL. We would like to perform the K^+ and K^- experiments in parallel, in order to compare the data in detail. Such a comparison appears to be very fruitful at lower energy.

The choice of 70 GeV/c for the momentum is based on the following considerations :

1°) - 70 GeV/c is the highest expected value at which the E.P.I. will be able to work (ref. 1).

2°) - 70 GeV/c is also the highest common available momentum for K^+ and K^- (ref.2).

Moreover this highest energy would allow an interesting comparison with the data already obtained at 32 GeV/c by the Serpukhov Mirabelle experiments and consequently would give information on s dependence of the various processes.

Obviously this proposal may be modified if new experimental results or new theoretical ideas are published.

In a letter of intent, sent to the S.P.S.C. last year (ref.3) we proposed to study $K^{\pm}p$ interactions in BEBC operated in an hybrid — mode, that means not only with a downstream charged particle identifier, but also with a TST and a forward γ ray detector. Nevertheless in that letter we had emphasized that if the TST and the forward γ ray detector were not yet installed by 1976, as it seems now to be the case, a rich class of events could still be analysed with the help of the E.P.I. alone, downstream of BEBC. Consequently the object of this letter is to propose an experiment using BEBC filled with hydrogen together with an external particle identifier. We know that other letters of intent for K^+p or K^-p interactions have been sent requesting roughly the same amount of pictures and proposing the same kind of physics (ref.4) at momenta slightly different from 70 GeV/c.

As will be shown below, our data reduction facilities are not sufficient for performing the proposed experiment alone, so we shall collaborate with some other laboratories.

In the following, we present the main physics subjects of interest, and using known results, an estimation of the experimental sample.

II-PHYSICS INTERESTS

The versatility of the bubble chamber in studying almost any kind of interaction with a 4π solid angle acceptance leads to expect an overall view of the hadron interactions at an intermediate energy between the well known low energy region and the very high-energy ISR region. It is generally admitted now that these interactions are mainly due to two different mechanisms:

- diffraction mechanism
- multiperipheral mechanisms.

From published data, Harari has shown (ref.5) that the diffractive component to the total inelastic cross section for pp interactions above p_{lab} =50 GeV/c is of the order of 16%. The comparison of K^+ and K^- data is very useful in disentangling the contribution of diffractive and non-diffractive mechanisms. Since many exclusive channels will be studied in addition to inclusive reactions, new information is expected which may not have been covered by earlier FNAL experiments. Indeed BEBC and the facilities around it, allow refined results for all multiplicities, even for the highest ones.

The main experimental aims of the proposed experiment are :

1°)-Cross-sections and multiplicities

We can expect to get a complete description of the charged particle multiplicity distributions and cross-sections as well as informations on the production of neutral particles, $\gamma, \Lambda^\circ, K^\circ, \pi^\circ$. Whereas the question of the rise of the KN total cross-section seems to be now confirmed (ref 6), we may find information on the contribution of each topological or channel cross section.

Multiplicity distributions are found to be of great importance in the understanding of reaction mechanisms. Up to now (ref. 7) the various multiplicity moments and the possible approaches to scaling suggest that

2°) Non diffractive processes

About 80% of the events presumably may be attributed to these processes and they mostly exhibit high charge multiplicity. Of course, we shall study inclusive and semi-inclusive distributions for all kinds of particles and for resonances like K^*, Y^* and Δ, including some neutrals. A great variety of particles should be identified by the EPI without the help of kinematical fits. We shall look at the charge and strangeness transfer distributions and try to find the isospin and strangeness structure of the amplitude.

Among the most interesting subjects of this proposal, we must quote the study of correlations in the central region, including the particle-antiparticle pairs. The search for clusters of secondaries seems to be very promising. A priori it does not seem possible to distinguish clusters by looking at the rapidity distributions in individual events, but it is still possible to use a statistical method to detect their existence (ref.8). Anyhow the analysis of the structure of individual events may provide some significant information. Finally, multiperipheral models also may be tested by looking at specific classes of exclusive final states. Also the comparison of K^+ and K^- data may help to test factorisation rules in the Mueller-Regge framework.

3°)- Diffractive dissociation processes

We can study elastic and inelastic diffraction processes down to small t values. We shall especially look at the kaon diffraction and this may be easy using the forward EPI. The events are expected to exhibit low multiplicity ($n \simeq 3$) and large rapidity gaps.

We shall look for $Q^{\pm} \to K^*_{890}\,\pi$ and $L^{\pm} \to K^*_{1420}\,\pi$ production. The $K^{\pm}p \to Q^{\pm}p$ cross-section extrapolated from published data (Ref.9), are both of the order of 100 μb at 70 GeV/c. If this extrapolation is valid, we are in good condition to observe the signals ; indeed for a 25 events/μb experiment, one would expect 2500 such events.

The selection of such events should be less troublesome than at lower energies, since background contamination, mainly due to Δ^{++}, should be lower as expected from phase-space arguments. Hence we can expect to easily check the σ_{Q^+} and σ_{Q^-} equality, compare the shapes of $d\sigma/dt$, of the $M_{K\pi\pi}$ bump, look for a remaining cross-over phenomena. We may also detect double diffraction dissociation as it has been observed at lower energy ; for instance at 14 GeV/c

$$\sigma \left[K^- p \rightarrow Q^- (\Delta \pi)_{1450}\right] \sim 7 \ \mu b \qquad \text{(ref. 10)}$$

Finally , as it has been seen for the 3π system (ref.11) we may look for other bumps in the $K\pi\pi$ mass spectrum at higher mass value, e.g. $X_{2150} \rightarrow K^*_{1760}\pi$. We shall also search diffraction signals in n-body ($n > 3$) final state and maybe, contribute to the knowledge of the variation of the mean diffractive multiplicity as a function of s.

4°) Other quasi-two-body reactions

At 70 GeV/c, the particles produced at the two vertices of an exchange diagram would be well separated. So in spite of rather small cross-sections and of the important rate of diffractive processes, it may be possible to isolate some channels due to Reggeon (e.g. pion) exchange and to get some dynamic features. For example, the production of quasi-two-body reactions such as $K^{\pm} p \rightarrow K^{*\pm} p$ is expected to be of the order of a few microbarns according to the formula $\sigma_{(p\ lab)} \sim p^{-n}_{Lab}$.

From Serpukhov results (ref.12), we foresee the following rates at 70 GeV /c

$K^-p \rightarrow K^*_{890}p$; $(n \sim 1.5)$; $\sigma = 8\ \mu b$ nbr of evts expected : 50 (K°_{seen})

$K^-p \rightarrow K^*_{1420}p$: $(n \sim .8)$; $\sigma = 12\ \mu b$ nbr of evts expected: 70 (K°_{seen})

A check of the validity of this law can be done and if cross-sections are not lower than expected, some information about $\frac{d\sigma}{dt}$ can be extracted.

Indeed, this study would be better done with counters, but the bubble chamber experiment can provide earlier crude information on this subject.

5°) Search for rare particles

Finally we shall look for production of heavy particles like Ξ, Ω

III- STATISTICAL SAMPLE

1°) Total number of interactions. This experiment is intended to detect channels corresponding to cross-sections of the order of microbarn. For a first experiment, 25 evts/ μb seems to be reasonable. Then, with 10 incident particles per picture, and 2.5m of length for the useful volume (see fig.3) this leads to 300,000 pictures for each charge, $K^{\pm}$ in BEBC. The total cross-sections (ref. 16) and consequently the corresponding numbers of events are :

$$\sigma_{tot}(K^+p) = 18.4 \pm .3\text{mb} \qquad 450,000 \pm 8,000 \text{ evts}$$

$$\sigma_{tot}(K^-p) = 20.2 \pm .3\text{mb} \qquad 500,000 \pm 8,000 \text{ evts}$$

2°) Topological cross-sections. For estimating the topological cross-sections we have extrapolated up to 70 GeV/c (fig 1 and 2) the published data obtained at lower energy including the Serpukhov experiment done at 32 GeV/c (ref. 13). To be sure that these extrapolations are not unreasonable, we can use them for computing the average charge multiplicity $\langle n_c \rangle$ and the average charge dispersion $D = \left[\langle n_c^2 \rangle - \langle n_c \rangle^2\right]^{1/2}$ and verify that the results (column II of table I) are in agreement with the predicted values, i.e. the values determined by linear extrapolations in log s from lower energy data (column I of table I).

3°) Decay observation. A large bubble chamber like BEBC is well suited for the detection of particle decays. Table III shows the mean decay lengths of various particles versus their momentum and the corresponding detection efficiency, using the fiducial volume shown in fig-3.

a) V° sample-The V°'s are due to K° and Λ° decays and to γ conversion inside the chamber.

For the K°_s, we make the assumption that the ratio $\dfrac{\sigma(K^{\pm}p \to K^\circ + X)}{\sigma_{inel}}$ is constant with s and of the order of 40%, as it is observed at lower energy (ref. 14). If we apply this result to each charged multiplicity taking into account a mean detection efficiency equal to 50% for the decay $K^\circ_s \to \pi^+\pi^-$, we obtain the numbers listed in table IV. This procedure must be considered as a very first approximation. We know that the multiplicities would be different from those listed below.

For the Λ°, the situation is not as simple as for the K°_s, but the last results of 32 GeV/c $K^\pm p$ Serpukhov bubble chamber experiments give useful results for the prediction at 70 GeV/c (ref. 15). A crude extrapolation of the results is given in table V taking into account a mean detection efficiency equal to 50%.

We underline that we expect to obtain a rather large sample of multi V° events corresponding for instance to non hypercharge annihilations channels. Thus the Λ° K and K ° K° K° cross-sections should go up to values between 1 and 2 mb.

In addition, we must take care of γ conversion. The γ conversion probability inside BEBC filled up with hydrogen is of the order of 10% and the total number of $e^+ e^-$ pairs simulating at the scanning level a V°, will be high. Indeed, if we make the hypothesis that the mean π° multiplicity is of the order of half the mean charged multiplicity, this leads to at least 1.5 γ converted per picture. However it has been found in pp interactions at 70GeV/c studied with Mirabelle, that after kinematical fits , the remaining γ/Λ° and γ/K° ambiguities are very small (ref.16). Furthermore, the γ observation may be very useful in itself, for π° detection and for Λ°/Ξ° ambiguity resolution.

b) Production of Ξ and Ω

A fairly good sample of Ξ and Ω decays would be obtained at least in the K^-p pictures. Assuming that the total inclusive Ξ and Ω cross-sections remain constant from 10 to 70 GeV/c we get :

$K^-p \to \Xi^- X$	$\sigma = 70$ μb	n evts:	1000	(ref. 17)
$K^+p \to \overline{\Xi}^+ X$	" = 10 "	n evts:	150	(ref. 18)
$K^+p \to \Xi^- X$	" = 2.5 "	n evts:	40	(ref. 18)
$K^-p \to \Omega^- X$	" = 5.9 "	all modes		(ref. 19)
$\Omega^- \to \Lambda K$	= 2.5 μb	nb évts :	40	

IV - DATA COLLECTION

a) Problem of ambiguities

The problems arising with ambiguities have been extensively treated in ECFA report (ref. 20). The first measurements done with BEBC confirm the value of 300μ for the setting error. Then it is reasonable to admit the conclusion of this report. It is shown there that it would be hard to get even ambiguous 4C fits without the help of external devices. Indeed the setting up of a charge particle identifier (EPI) would solve at least K^+/π^+ or K^-/π^- ambiguities for the 4C fitted events. We shall certainly restrict our exclusive studies to the 4 C channels, including may-be some events with π^0 production, for which the γ's are converted.

However, the system (BEBC + EPI) allows the study of non fitted events because a rather good proportion of particles will be measured and identified without the help of kinematical fit. From ref. 21, we know that about 75% of the forward tracks will be identified. This may be sufficient, for instance, for the study of known diffraction peaks.

b) Analysis power

We shall have five scanning tables, two film plane digitizers and at least one CRT device (ref.23). This corresponds to a measurement power of the order of 10^5 events per year. As underlined in the introduction, we would like to share films with the collaborations that have already proposed experiments for K^+ or K^-. At the end of 1976 the number of physicists of our laboratory available for performing this experiment will be of the order of 14, that means two groups of 7.

We shall have at this time some experience of handling BEBC pictures since we are involved in the K^-p at 8,25 GeV/c in BEBC ; furthermore other physicists of the group are now working in K^+p at 32 GeV/c in Mirabelle.

For this proposal the contact physicists will be

M. Baubillier (K^-) and J. Laberrigue (K^+).

TABLE I

		I	II
$\langle n_c \rangle$	K^+	6.2 ± 0.2	6.2
	K^-	5.9 ± 0.2	6.0
D	K^+	2.7 ± 0.1	2.9
	K^-	2.9 ± 0.1	3

Average multiplicity and dispersion

(I) predicted by linear extrapolations of published data
(II) calculated from our topological cross section estimations , listed in table II. (they do not include the elastic channels).

TABLE II

K^+			K^-		
Prongs	$\sigma K^+ p_{(mb)}$	nb evts	$\sigma K^- p_{(mb)}$	nb evts	Prongs
0			0.21 ± 0.05	5000	0
2 incl	2.2 ± 0.3	55 000	2.7 ± .3	70 000	2 incl
4	3.7 ± 0.3	90 000	4 ± .3	100 000	4
6	3.4 ± 0.3	85 000	4.7 ± .3	120 000	6
8	3.5 ± 0.3	90 000	3.7 ± .3	90 000	8
10	1.6 ± 0.3	40 000	1.7 ± .2	40 000	10
12	.85 ± 0.1	20 000	.7 ± .2	20 000	12
14	.15 ± 0.05	5 000 *	.23 ± 0.2	5 000 *	14
16	.01 ± 0.005	500 *	.05 ± .03	500 *	16
Total	15.4 ± .5	385 000	18.0 ± .6	450 000	Total

Extrapolated cross sections and estimated number of events

TABLE III

Particles	mean decay length and detection efficiency					
	30 GeV/c	eff	50 GeV/c	eff.	70 GeV/c	eff.
K°_s	160 cm	63%	260cm	47%	360	37%
Λ°	200 cm	55%	340cm	39%	470	31%
Σ^+	60 cm	90%	100 cm	78%	140	67%
Σ^-	120 cm	72%	200 cm	55%	280	45%
Ξ^-	110 cm	75%	180 cm	60%	260	47%
Ω^-	70 cm	87%	120 cm	72%	160	63%

BEBC Particle decay efficiency

TABLE IV

	K^+p		K^-p	
	σK°	nb evts seen	σK°	nb evts seen
0	/	/	$.03 \pm .01$	350
2	$.88 \pm .2$	3500	$1.1 \pm .2$	4500
4	$1.5 \pm .1$	6200	$1.6 \pm .2$	6700
6	$1.4 \pm .1$	6000	$1.9 \pm .2$	7700
8	$1.5 \pm .1$	6500	$1.5 \pm .2$	6300
10	$.6 \pm .1$	2800	$.7 \pm .1$	2800
12	$.30 \pm .03$	1500	$.30 \pm .1$	1500
14	$.06 \pm .03$	300	$.09 \pm .03$	300
16	$.004 \pm .01$	50	$.02 \pm .01$	50
TOTAL	$6.2 \pm .5$	27000	$7.3 \pm .5$	30 000

TABLE V

	K^+p		K^-p	
	σ mb	nb events	σ mb	nb events
Λ° (Ξ°)	2	16 000	2	16 000
$\bar{\Lambda}^\circ$ ($\bar{\Xi}^\circ$)	.5	4 000	.1	800

Λ° decay in BEBC for 300 000 $K^\pm$ pictures

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FIGURE CAPTIONS

- figure I- K^+p topological cross sections.
- figure II- K^-p topological cross sections.
- figure III- BEBC fiducial volumes.

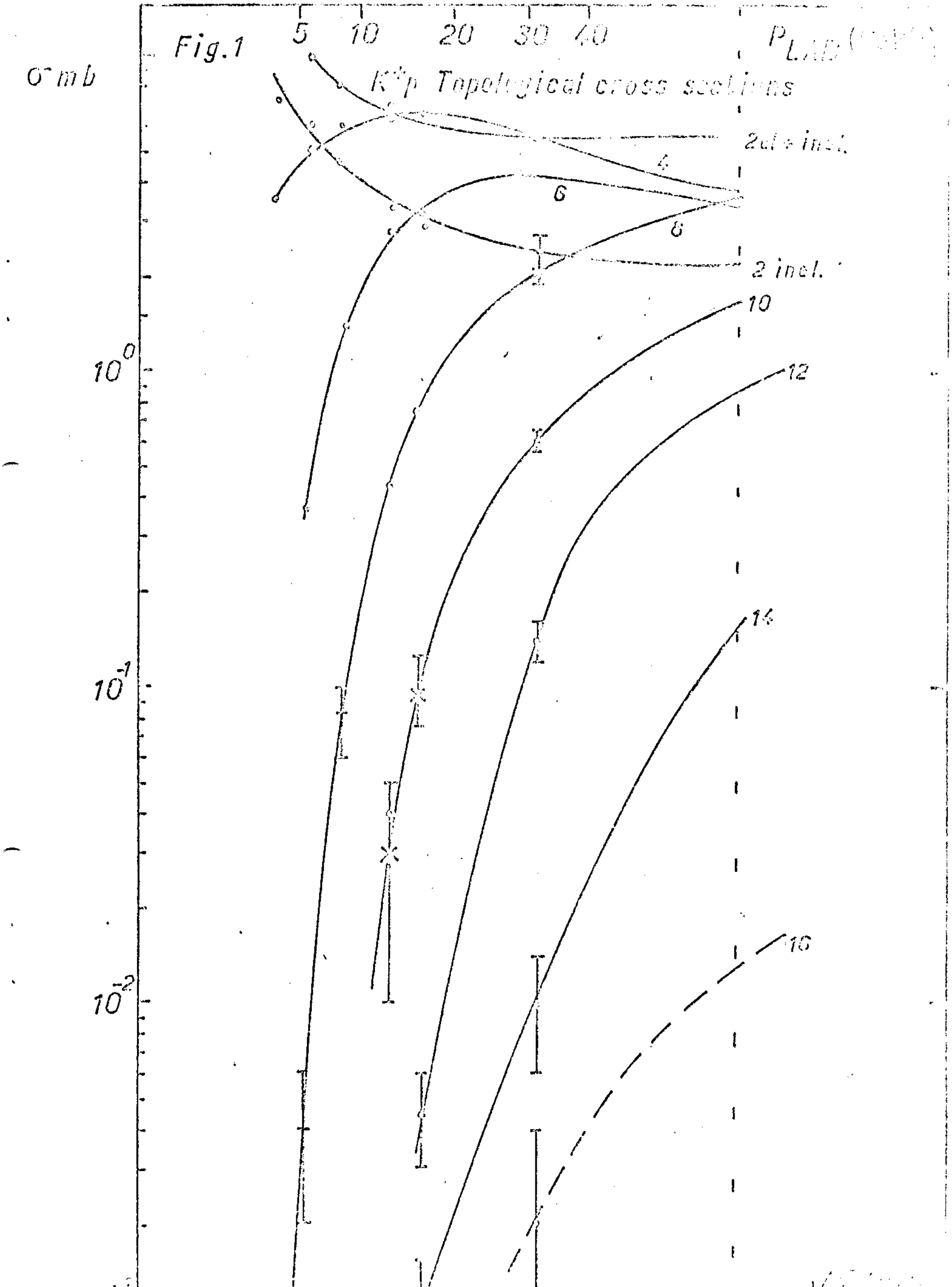


Fig.1
σ mb
5
10
20
30
40
P_{LAB}
K^+p Topological cross sections
2el + inel.
4
6
8
2 inel.
10
12
14
16
10^0
10^{-1}
10^{-2}

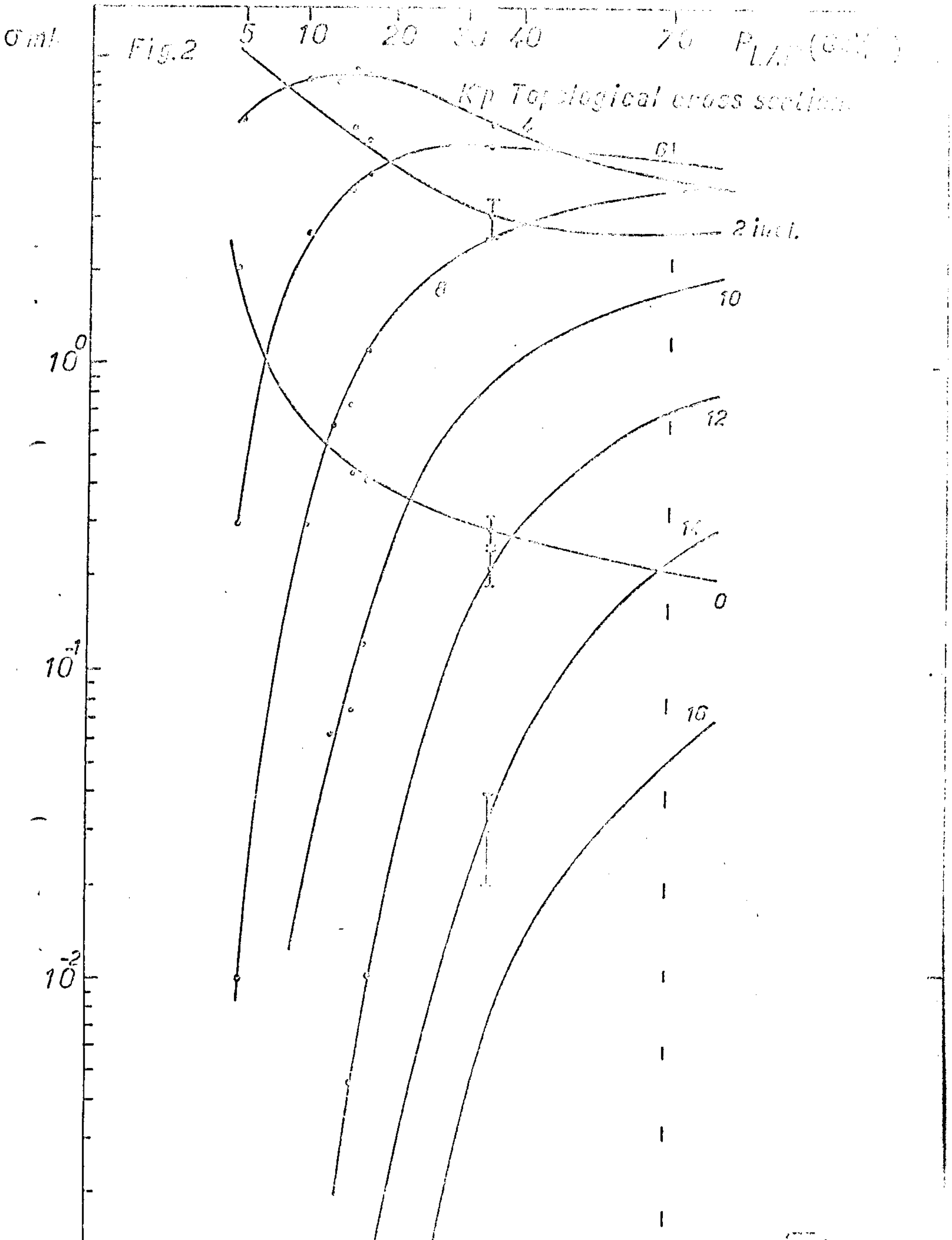
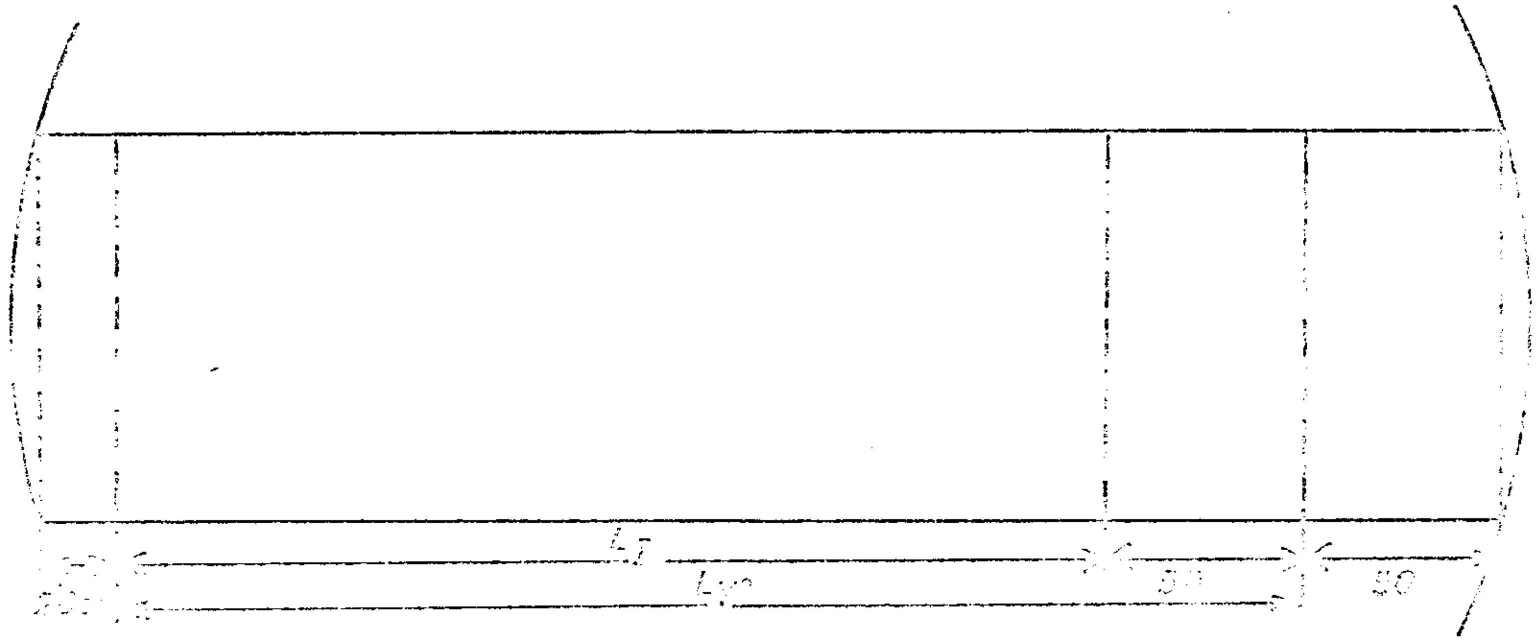

σ mb
Fig.2
5
10
20
30
40
70
P_{LAB} (GeV)
K⁻p Topological cross section
4
6
2 incl.
8
10
12
14
0
16
10^{0}
10^{-1}
10^{-2}

Fig. 3 — BEBC Fiducial volumes



L_I – Length of the primary vertex fiducial volume.

L_{V^0} – Length of the V° fiducial volume.

$L_I = 250\,cm$ $L_{V^0} = 300\,cm$